PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
P/61757/PC		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/GB 00/ 02418	22/06/2000	23/06/1999
Applicant		
MARCONI CASWELL LIMITED		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language,** the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

   [ ] furnished subsequently to this Authority in computer readble form.

   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of Invention is lacking** (see Box II).

4. With regard to the **title,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 3

   [X] as suggested by the applicant.

   [ ] because the applicant failed to suggest a figure.

   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.

INTERNATIONAL SEARCH REPORT

Int[redacted]nal Application No
PCT/GB 00/02418

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01L41/107

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
INSPEC, COMPENDEX, EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KUANG A X ET AL: "Piezoelectric ceramic transformer high voltage power supply" ISAF '86. PROCEEDINGS OF THE SIXTH IEEE INTERNATIONAL SYMPOSIUM ON APPLICATIONS OF FERROELECTRICS, BETHLEHEM, PA, USA, 8 - 11 June 1986, pages 689-692, XP002147549 IEEE, New York, USA	1-3,7, 11, 15-17, 20,22,26
Y	the whole document	4-6,13, 14,18, 19,28,29
Y	US 5 866 968 A (MECH HAROLD W) 2 February 1999 (1999-02-02) column 1, line 11 -column 5, line 54 column 7, line 37 - line 41 figures 1,2	4-6,18, 19

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 September 2000	29/09/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Köpf, C

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 736 446 A (BERLINCOURT DON A ET AL) 29 May 1973 (1973-05-29) column 1, line 8 -column 6, line 41 column 10, line 16 -column 11, line 56 figures 1,7,10	1-3, 9-12, 15-17, 23-27
X	LI LONGTU ET AL: "Lead zirconate titanate ceramics and monolithic piezoelectric transformer of low firing temperature" FERROELECTRICS, vol. 101, 1990, pages 193-200, XP002043424 ISSN: 0015-0193	31,32
Y	the whole document	13,14, 28,29
X	PATENT ABSTRACTS OF JAPAN vol. 1999, no. 01, 29 January 1999 (1999-01-29) & JP 10 279354 A (HITACHI METALS LTD), 20 October 1998 (1998-10-20)	31,32
Y	abstract -& JP 10 279354 A (HITACHI METALS LTD) 20 October 1998 (1998-10-20) figure 4; table 1	13,14, 28,29
A	EP 0 665 600 A (HITACHI METALS LTD) 2 August 1995 (1995-08-02) cited in the application page 9, line 45 -page 12, line 32; figures 13,18,28	1-3,7, 11, 13-17, 20,26, 28-33
A	US 5 792 379 A (DAI XUNHU ET AL) 11 August 1998 (1998-08-11) the whole document	31,32
A	KIM J-S ET AL: "Piezoelectric and dielectric properties of Fe2O3-doped 0.57Pb(Sc1/2Nb1/2)O3-0.43PbTiO3 ceramic materials" JAPANESE JOURNAL OF APPLIED PHYSICS, PART 1 (REGULAR PAPERS, SHORT NOTES & REVIEW PAPERS), vol. 38, no. 3A, March 1999 (1999-03), pages 1433-1437, XP002147550 ISSN: 0021-4922 the whole document	31

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 00/02418

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5866968 A	02-02-1999	EP 1008190 A	14-06-2000
		WO 9850966 A	12-11-1998
US 3736446 A	29-05-1973	FR 1584011 A	12-12-1969
		GB 1241221 A	04-08-1971
		GB 1241222 A	04-08-1971
		US 3562792 A	09-02-1971
JP 10279354 A	20-10-1998	NONE	
EP 0665600 A	02-08-1995	JP 7220888 A	18-08-1995
		JP 8045681 A	16-02-1996
		JP 8069890 A	12-03-1996
		DE 69510835 D	26-08-1999
		DE 69510835 T	16-03-2000
		US 5705879 A	06-01-1998
US 5792379 A	11-08-1998	EP 1021386 A	26-07-2000
		WO 9843925 A	08-10-1998

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark Office, PCT
2011 South Clark Place Room CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 02 March 2001 (02.03.01)	
International application No. PCT/GB00/02418	**Applicant's or agent's file reference** P/61757.WOP/
International filing date (day/month/year) 22 June 2000 (22.06.00)	**Priority date** (day/month/year) 23 June 1999 (23.06.99)
Applicant SALLOWAY, Anthony, John et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

17 January 2001 (17.01.01)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer Olivia TEFY
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

Form PCT/IB/331 (July 1992)

GB0002418

Copy for the designated Office (DO/US)

PCT/GB00/02418

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

To:

TOLFREE, Roger, Keith
Marconi Intellectual Property
Waterhouse Lane
Chelmsford
Essex CM1 2QX
ROYAUME-UNI

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

Date of mailing (day/month/year) 26 February 2001 (26.02.01)	
Applicant's or agent's file reference P/61757.WOP/	**IMPORTANT NOTIFICATION**
International application No. PCT/GB00/02418	**International filing date** (day/month/year) 22 June 2000 (22.06.00)

1. The following indications appeared on record concerning:

☐ the applicant ☐ the inventor ☒ the agent ☐ the common representative

Name and Address

COCKAYNE, Gillian
Marconi Intellectual Property
Waterhouse Lane
Chelmsford
Essex CM1 2QX
United Kingdom

State of Nationality:

State of Residence:

Telephone No.: 44 0 1245 275459

Facsimile No.: 44 0 1245 275114

Teleprinter No.:

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

☒ the person ☐ the name ☐ the address ☐ the nationality ☐ the residence

Name and Address

TOLFREE, Roger, Keith
Marconi Intellectual Property
Waterhouse Lane
Chelmsford
Essex CM1 2QX
United Kingdom

State of Nationality:

State of Residence:

Telephone No.: 44 0 1245 275563

Facsimile No.: 44 0 1245 275469

Teleprinter No.:

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

☒ the receiving Office
☐ the International Searching Authority
☐ the International Preliminary Examining Authority
☒ the designated Offices concerned
☐ the elected Offices concerned
☐ other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer

R. Chrem

Telephone No.: (41-22) 338.83.38

INTERNATIONAL SEARCH REPORT

Inter[redacted]Application No
PCT/GB 00/02418

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01L41/107

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
INSPEC, COMPENDEX, EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KUANG A X ET AL: "Piezoelectric ceramic transformer high voltage power supply" ISAF '86. PROCEEDINGS OF THE SIXTH IEEE INTERNATIONAL SYMPOSIUM ON APPLICATIONS OF FERROELECTRICS, BETHLEHEM, PA, USA, 8 - 11 June 1986, pages 689-692, XP002147549 IEEE, New York, USA	1-3,7, 11, 15-17, 20,22,26
Y	the whole document	4-6,13, 14,18, 19,28,29
Y	US 5 866 968 A (MECH HAROLD W) 2 February 1999 (1999-02-02) column 1, line 11 -column 5, line 54 column 7, line 37 - line 41 figures 1,2	4-6,18, 19

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 September 2000	29/09/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Köpf, C

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

...formation on patent family members

Inter... Application No
PCT/GB 00/02418

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5866968 A	02-02-1999	EP 1008190 A	14-06-2000
		WO 9850966 A	12-11-1998
US 3736446 A	29-05-1973	FR 1584011 A	12-12-1969
		GB 1241221 A	04-08-1971
		GB 1241222 A	04-08-1971
		US 3562792 A	09-02-1971
JP 10279354 A	20-10-1998	NONE	
EP 0665600 A	02-08-1995	JP 7220888 A	18-08-1995
		JP 8045681 A	16-02-1996
		JP 8069890 A	12-03-1996
		DE 69510835 D	26-08-1999
		DE 69510835 T	16-03-2000
		US 5705879 A	06-01-1998
US 5792379 A	11-08-1998	EP 1021386 A	26-07-2000
		WO 9843925 A	08-10-1998

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

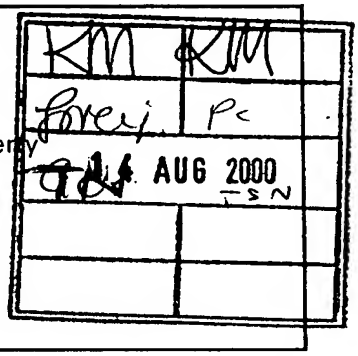
PCT

NOTIFICATION OF RECEIPT OF RECORD COPY

(PCT Rule 24.2(a))

To:

COCKAYNE, Gillian
Marconi Intellectual Property
Waterhouse Lane
Chelmsford
Essex CM1 2QX
ROYAUME-UNI



Date of mailing (day/month/year)	**IMPORTANT NOTIFICATION**
04 August 2000 (04.08.00)	
Applicant's or agent's file reference	**International application No.**
P/61757/PC	PCT/GB00/02418

The applicant is hereby notified that the International Bureau has received the record copy of the international application as detailed below.

Name(s) of the applicant(s) and State(s) for which they are applicants:

MARCONI CASWELL LIMITED (for all designated States except US)
SALLOWAY, Anthony, John et al (for US)

International filing date	:	22 June 2000 (22.06.00)
Priority date(s) claimed	:	23 June 1999 (23.06.99)
Date of receipt of the record copy by the International Bureau	:	20 July 2000 (20.07.00)
List of designated Offices	:	

AP :GH,GM,KE,LS,MW,MZ,SD,SL,SZ,TZ,UG,ZW
EA :AM,AZ,BY,KG,KZ,MD,RU,TJ,TM
EP :AT,BE,CH,CY,DE,DK,ES,FI,FR,GB,GR,IE,IT,LU,MC,NL,PT,SE
OA :BF,BJ,CF,CG,CI,CM,GA,GN,GW,ML,MR,NE,SN,TD,TG
National :AE,AG,AL,AM,AT,AU,AZ,BA,BB,BG,BR,BY,CA,CH,CN,CR,CU,CZ,DE,DK,DM,DZ,EE,ES, FI,GB,GD,GE,GH,GM,HR,HU,ID,IL,IN,IS,JP,KE,KG,KP,KR,KZ,LC,LK,LR,LS,LT,LU,LV,MA,MD, MG,MK,MN,MW,MX,MZ,NO,NZ,PL,PT,RO,RU,SD,SE,SG,SI,SK,SL,TJ,TM,TR,TT,TZ,UA,UG,US,UZ, VN,YU,ZA,ZW

ATTENTION

The applicant should carefully check the data appearing in this Notification. In case of any discrepancy between these data and the indications in the international application, the applicant should immediately inform the International Bureau.

In addition, the applicant's attention is drawn to the information contained in the Annex, relating to:

- [X] time limits for entry into the national phase
- [X] confirmation of precautionary designations
- [X] requirements regarding priority documents

A copy of this Notification is being sent to the receiving Office and to the International Searching Authority.

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. (41-22) 740.14.35

Authorized officer:

Anman QIU

Telephone No. (41-22) 338.83.38

INFORMATION ON TIME LIMITS FOR ENTERING THE NATIONAL PHASE

The applicant is reminded that the "national phase" must be entered before each of the designated Offices indicated in the Notification of Receipt of Record Copy (Form PCT/IB/301) by paying national fees and furnishing translations, as prescribed by the applicable national laws.

The time limit for performing these procedural acts is **20 MONTHS** from the priority date or, for those designated States which the applicant elects in a demand for international preliminary examination or in a later election, **30 MONTHS** from the priority date, provided that the election is made before the expiration of 19 months from the priority date. Some designated (or elected) Offices have fixed time limits which expire even later than 20 or 30 months from the priority date. In other Offices an extension of time or grace period, in some cases upon payment of an additional fee, is available.

In addition to these procedural acts, the applicant may also have to comply with other special requirements applicable in certain Offices. **It is the applicant's responsibility** to ensure that the necessary steps to enter the national phase are taken in a timely fashion. Most designated Offices do not issue reminders to applicants in connection with the entry into the national phase.

For detailed information about the procedural acts to be performed to enter the national phase before each designated Office, the applicable time limits and possible extensions of time or grace periods, and any other requirements, see the relevant Chapters of Volume II of the PCT Applicant's Guide. Information about the requirements for filing a demand for international preliminary examination is set out in Chapter IX of Volume I of the PCT Applicant's Guide.

GR and ES became bound by PCT Chapter II on 7 September 1996 and 6 September 1997, respectively, and may, therefore, be elected in a demand or a later election filed on or after 7 September 1996 and 6 September 1997, respectively, regardless of the filing date of the international application. (See second paragraph above.)

Note that only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination.

CONFIRMATION OF PRECAUTIONARY DESIGNATIONS

This notification lists only specific designations made under Rule 4.9(a) in the request. It is important to check that these designations are correct. Errors in designations can be corrected where precautionary designations have been made under Rule 4.9(b). The applicant is hereby reminded that any precautionary designations may be confirmed according to Rule 4.9(c) before the expiration of 15 months from the priority date. If it is not confirmed, it will automatically be regarded as withdrawn by the applicant. There will be no reminder and no invitation. Confirmation of a designation consists of the filing of a notice specifying the designated State concerned (with an indication of the kind of protection or treatment desired) and the payment of the designation and confirmation fees. Confirmation must reach the receiving Office within the 15-month time limit.

REQUIREMENTS REGARDING PRIORITY DOCUMENTS

For applicants who have not yet complied with the requirements regarding priority documents, the following is recalled.

Where the priority of an earlier national, regional or international application is claimed, the applicant must submit a copy of the said earlier application, certified by the authority with which it was filed ("the priority document") to the receiving Office (which will transmit it to the International Bureau) or directly to the International Bureau, before the expiration of 16 months from the priority date, provided that any such priority document may still be submitted to the International Bureau before that date of international publication of the international application, in which case that document will be considered to have been received by the International Bureau on the last day of the 16-month time limit (Rule 17.1(a)).

Where the priority document is issued by the receiving Office, the applicant may, instead of submitting the priority document, request the receiving Office to prepare and transmit the priority document to the International Bureau. Such request must be made before the expiration of the 16-month time limit and may be subjected by the receiving Office to the payment of a fee (Rule 17.1(b)).

If the priority document concerned is not submitted to the International Bureau or if the request to the receiving Office to prepare and transmit the priority document has not been made (and the corresponding fee, if any, paid) within the applicable time limit indicated under the preceding paragraphs, any designated State may disregard the priority claim, provided that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity to furnish the priority document within a time limit which is reasonable under the circumstances.

Where several priorities are claimed, the priority date to be considered for the purposes of computing the 16-month time limit is the filing date of the earliest application whose priority is claimed.

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

To:

COCKAYNE, Gillian
Marconi Intellectual Property
Waterhouse Lane
Chelmsford
Essex CM1 2QX
ROYAUME-UNI

NOTIFICATION CONCERNING SUBMISSION OR TRANSMITTAL OF PRIORITY DOCUMENT

(PCT Administrative Instructions, Section 411)

Date of mailing (day/month/year) 23 October 2000 (23.10.00)	
Applicant's or agent's file reference P/61757/PC – FILE WOP CWP PLS.	**IMPORTANT NOTIFICATION**
International application No. PCT/GB00/02418	International filing date (day/month/year) 22 June 2000 (22.06.00)
International publication date (day/month/year) Not yet published	Priority date (day/month/year) 23 June 1999 (23.06.99)
Applicant MARCONI CASWELL LIMITED et al	

1. The applicant is hereby notified of the date of receipt (except where the letters "NR" appear in the right-hand column) by the International Bureau of the priority document(s) relating to the earlier application(s) indicated below. Unless otherwise indicated by an asterisk appearing next to a date of receipt, or by the letters "NR", in the right-hand column, the priority document concerned was submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b).

2. This updates and replaces any previously issued notification concerning submission or transmittal of priority documents.

3. An **asterisk(*)** appearing next to a date of receipt, in the right-hand column, denotes a priority document submitted or transmitted to the International Bureau but not in compliance with Rule 17.1(a) or (b). In such a case, **the attention of the applicant is directed** to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

4. The **letters "NR"** appearing in the right-hand column denote a priority document which was not received by the International Bureau or which the applicant did not request the receiving Office to prepare and transmit to the International Bureau, as provided by Rule 17.1(a) or (b), respectively. In such a case, **the attention of the applicant is directed** to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

Priority date	Priority application No.	Country or regional Office or PCT receiving Office	Date of receipt of priority document
23 June 1999 (23.06.99)	9914516.1	GB	25 July 2000 (25.07.00)

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. (41-22) 740.14.35

Authorized officer

Magda BOUACHA

Telephone No. (41-22) 338.83.38

WO 01/01500
PCT/GB00/02418

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTICE INFORMING THE APPLICANT OF THE COMMUNICATION OF THE INTERNATIONAL APPLICATION TO THE DESIGNATED OFFICES

(PCT Rule 47.1(c), first sentence)

To:
COCKAYNE, Gillian
Marconi Intellectual Property
Waterhouse Lane
Chelmsford
Essex CM1 2QX
ROYAUME-UNI

12 JAN 2001

Date of mailing (day/month/year) 04 January 2001 (04.01.01)	
Applicant's or agent's file reference P/61757/PC	**IMPORTANT NOTICE**

International application No.	**International filing date** (day/month/year)	**Priority date** (day/month/year)
PCT/GB00/02418	22 June 2000 (22.06.00)	23 June 1999 (23.06.99)

Applicant
MARCONI CASWELL LIMITED et al

1. Notice is hereby given that the International Bureau has communicated, as provided in Article 20, the international application to the following designated Offices on the date indicated above as the date of mailing of this Notice:
   AG,AU,DZ,KP,KR,MZ,US

   In accordance with Rule 47.1(c), third sentence, those Offices will accept the present Notice as conclusive evidence that the communication of the international application has duly taken place on the date of mailing indicated above and no copy of the international application is required to be furnished by the applicant to the designated Office(s).

2. The following designated Offices have waived the requirement for such a communication at this time:
   AE,AL,AM,AP,AT,AZ,BA,BB,BG,BR,BY,CA,CH,CN,CR,CU,CZ,DE,DK,DM,EA,EE,EP,ES,FI,GB,GD,
   GE,GH,GM,HR,HU,ID,IL,IN,IS,JP,KE,KG,KZ,LC,LK,LR,LS,LT,LU,LV,MA,MD,MG,MK,MN,MW,MX,
   NO,NZ,OA,PL,PT,RO,RU,SD,SE,SG,SI,SK,SL,TJ,TM,TR,TT,TZ,UA,UG,UZ,VN,YU,ZA,ZW
   The communication will be made to those Offices only upon their request. Furthermore, those Offices do not require the applicant to furnish a copy of the international application (Rule 49.1(a-bis)).

3. Enclosed with this Notice is a copy of the international application as published by the International Bureau on
   04 January 2001 (04.01.01) under No. WO 01/01500

REMINDER REGARDING CHAPTER II (Article 31(2)(a) and Rule 54.2)

If the applicant wishes to postpone entry into the national phase until 30 months (or later in some Offices) from the priority date, **a demand for international preliminary examination** must be filed with the competent International Preliminary Examining Authority before the expiration of 19 months from the priority date.

It is the applicant's sole responsibility to monitor the 19-month time limit.

Note that only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination.

REMINDER REGARDING ENTRY INTO THE NATIONAL PHASE (Article 22 or 39(1))

If the applicant wishes to proceed with the international application in the **national phase**, he must, within 20 months or 30 months, or later in some Offices, perform the acts referred to therein before each designated or elected Office.

For further important information on the time limits and acts to be performed for entering the national phase, see the Annex to Form PCT/IB/301 (Notification of Receipt of Record Copy) and Volume II of the PCT Applicant's Guide.

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. (41-22) 740.14.35

Authorized officer
J. Zahra

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PCT/GB00/02418

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File

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

INFORMATION CONCERNING ELECTED OFFICES NOTIFIED OF THEIR ELECTION

(PCT Rule 61.3)

To:

TOLFREE, Roger, Keith
Marconi Intellectual Property
Waterhouse Lane
Chelmsford
Essex CM1 2QX
ROYAUME-UNI

Date of mailing (day/month/year) 02 March 2001 (02.03.01)		
Applicant's or agent's file reference P/61757.WOP/	**IMPORTANT INFORMATION**	
International application No. PCT/GB00/02418	**International filing date** (day/month/year) 22 June 2000 (22.06.00)	**Priority date** (day/month/year) 23 June 1999 (23.06.99)
Applicant MARCONI CASWELL LIMITED et al		

1. The applicant is hereby informed that the International Bureau has, according to Article 31(7), notified each of the following Offices of its election:

   AP :GH,GM,KE,LS,MW,MZ,SD,SL,SZ,TZ,UG,ZW
   EP :AT,BE,CH,CY,DE,DK,ES,FI,FR,GB,GR,IE,IT,LU,MC,NL,PT,SE
   National :AU,BG,CA,CN,CZ,DE,IL,JP,KP,KR,MN,NO,NZ,PL,RO,RU,SE,SK,US

2. The following Offices have waived the requirement for the notification of their election; the notification will be sent to them by the International Bureau only upon their request:

   EA :AM,AZ,BY,KG,KZ,MD,RU,TJ,TM
   OA :BF,BJ,CF,CG,CI,CM,GA,GN,GW,ML,MR,NE,SN,TD,TG
   National :AE,AG,AL,AM,AT,AZ,BA,BB,BR,BY,CH,CR,CU,DK,DM,DZ,EE,ES,FI,GB,GD, GE,GH,GM,HR,HU,ID,IN,IS,KE,KG,KZ,LC,LK,LR,LS,LT,LU,LV,MA,MD,MG,MK,MW,MX, MZ,PT,SD,SG,SI,SL,TJ,TM,TR,TT,TZ,UA,UG,UZ,VN,YU,ZA,ZW

3. The applicant is reminded that he must enter the "national phase" **before the expiration of 30 months from the priority date** before each of the Offices listed above. This must be done by paying the national fee(s) and furnishing , if prescribed, a translation of the international application (Article 39(1)(a)), as well as, where applicable, by furnishing a translation of any annexes of the international preliminary examination report (Article 36(3)(b) and Rule 74.1).

   Some offices have fixed time limits expiring later than the above-mentioned time limit. For detailed information about the applicable time limits and the acts to be performed upon entry into the national phase before a particular Office, see Volume II of the PCT Applicant's Guide.

   The entry into the European regional phase is postponed **until 31 months from the priority date** for all States designated for the purposes of obtaining a European patent.

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No. (41-22) 740.14.35	Authorized officer: Olivia TEFY Telephone No. (41-22) 338.83.38

Form PCT/IB/332 (September 1997)

3874709

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
P/61757/PC		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB00/02418	22/06/2000	23/06/1999
International Patent Classification (IPC) or national classification and IPC H01L41/107		
Applicant MARCONI CASWELL LIMITED et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 6 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
17/01/2001	06.11.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Korb, W Telephone No. +49 89 2399 2284

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/02418

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

1-18 as originally filed

Claims, No.:

1-33 as originally filed

Drawings, sheets:

1/4-4/4 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	
	No:	Claims	1 - 3, 7, 11, 15 - 17, 20, 22, 26, 31
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1 - 33
Industrial applicability (IA)	Yes:	Claims	1 - 33
	No:	Claims	

2. Citations and explanations
see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

Re Item V

Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Reference is made to the following documents:

D1: KUANG A X ET AL: 'Piezoelectric ceramic transformer high voltage power supply' ISAF '86. PROCEEDINGS OF THE SIXTH IEEE INTERNATIONAL SYMPOSIUM ON APPLICATIONS OF FERROELECTRICS, BETHLEHEM, PA, USA, 8 - 11 June 1986, pages 689-692, XP002147549 IEEE, New York, USA

D2: LI LONGTU ET AL: 'Lead zirconate titanate ceramics and monolithic piezoelectric transformer of low firing temperature' FERROELECTRICS, vol. 101, 1990, pages 193-200, XP002043424 ISSN: 0015-0193

D3: PATENT ABSTRACTS OF JAPAN vol. 1999, no. 01, 29 January 1999 (1999-01-29) & JP 10 279354 A (HITACHI METALS LTD), 20 October 1998 (1998-10-20) -& JP 10 279354 A (HITACHI METALS LTD) 20 October 1998 (1998-10-20)

D4: KIM J-S ET AL: 'Piezoelectric and dielectric properties of Fe2O3-doped 0.57Pb(Sc1/2Nb1/2)O3-0.43PbTiO3 ceramic materials' JAPANESE JOURNAL OF APPLIED PHYSICS, PART 1 (REGULAR PAPERS, SHORT NOTES & REVIEW PAPERS), vol. 38, no. 3A, March 1999 (1999-03), pages 1433-1437, XP002147550 ISSN: 0021-4922

D5: US-A-3 736 446 (BERLINCOURT DON A ET AL) 29 May 1973 (1973-05-29)

D7: EP-A-0 665 600 (HITACHI METALS LTD) 2 August 1995 (1995-08-02) cited in the application

D6: US-A-5 792 379 (DAI XUNHU ET AL) 11 August 1998 (1998-08-11)

D8: US-A-5 866 968 (MECH HAROLD W) 2 February 1999 (1999-02-02)

The following document was not cited in the international search report. A copy of the document is appended hereto.

D9: US-A-4 405 480

2. Hard piezo-electric materials within the scope of the hard piezo-electric material according to the characterizing portion of claim 1 are well known from each of documents D1 - D4, D9 (see D1, page 690; D2, abstract, page 195; D3, Patent abstracts of Japan and JP-A-10 279 354, page 4, table; D4, page 1436, table; D9, columns 5, 6, table) and have already been applied in a piezo-electric transformer circuit according to the preamble of claim 1, see for example document D1 (see D1, page 690). In consequence the subject-matter claimed in claim 1 is not new. This applies analogously to the piezo-electric transformer claimed in claim 31.

3. The method claimed in claim 15 is likewise already known from, for example D1 (see D1, page 690).

4. Dependent claims 2 - 14, 16 - 30, 32, 33 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of novelty and/or inventive step, the reasons being as follows:

   The additional features are either already known from document D1 or can be derived from documents D1 - D9.

   The use of the known piezo-electric transformer in an apparatus as claimed in claim 33 and, in as much as it can be understood, in an apparatus as claimed in claim 30 is obvious and cannot establish an inventive merit.

Re Item VII

Certain defects in the international application

Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the documents D1 - D4, D9 is not mentioned in the description, nor are these documents identified therein.

Re Item VIII

Certain observations on the international application

1. The apparatus claimed in claim 30 refers to method claims without defining any concrete apparatus features. From the method claims however it is not clear which essential features of an apparatus are required for carrying out the method steps claimed. Thus the requirements of Article 6 PCT are not met.

2. Although claims 1 and 31 have been drafted as separate independent claims, they appear to relate effectively to the same subject-matter and to differ from each other only with regard to the definition of the subject-matter for which protection is sought and/or in respect of the terminology used for the features of that subject-matter. The aforementioned claims therefore lack conciseness. Moreover, lack of clarity of the claims as a whole arises, since the plurality of independent claims makes it difficult, if not impossible, to determine the matter for which protection is sought, and places an undue burden on others seeking to establish the extent of the protection.

   Hence, claims 1, 31 do not meet the requirements of Article 6 PCT.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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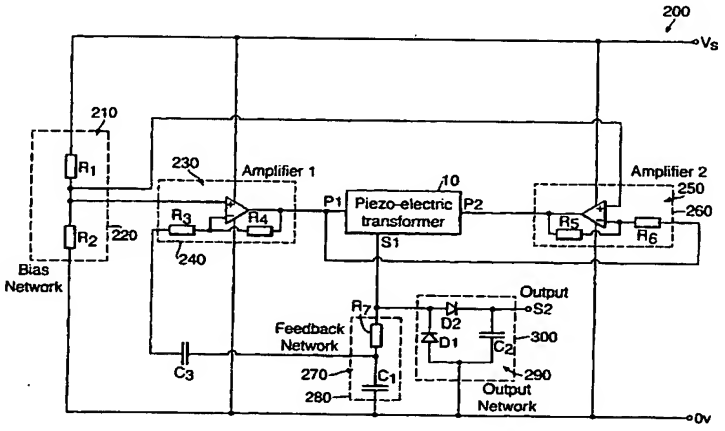
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: PIEZO-ELECTRIC TRANSFORMER CIRCUIT



(57) Abstract: The invention relates to a piezo-electric transformer circuit (200) incorporating a piezo-electric transformer (10) comprising a multi-element primary region (12) and a single element secondary region (14) mutually joined together. In operation, the circuit (200) applies a drive signal to the primary region (12) to excite the primary and secondary regions (12, 14) into longitudinal resonance, thereby generating a high potential signal at the secondary region (14). The drive signal is derived from the signal at the secondary region (14) in a self oscillating feedback loop configuration. The transformer (10) is fabricated from a hard piezo-electric ceramic material having a dielectric loss of substantially 0.005 or less at 1 kHz. Although such a hard ceramic does not provide as high a charge coefficient as softer piezo-electric ceramic materials, it is found that hard ceramics provide surprisingly improved energy conversion when used in piezo-electric transformer power supplies.

WO 01/01500 A1

PIEZO-ELECTRIC TRANSFORMER CIRCUIT

This invention relates to a piezo-electric transformer circuit and a method of operating the circuit.

Man-made piezo-electric materials such as lead zirconate titanate (PZT) are well known. The materials are often in the form of powders which can be sintered at elevated temperatures to form polycrystalline solids which can then be machined into components operable to couple between acoustic or vibrational radiation and corresponding electrical signals. The components can include, for example, ultrasonic transducers, microactuators and piezo-electric transformers.

Piezo-electric transformers are conventionally employed in power supply circuits providing high output potentials at low currents; in this context, high potential or high voltage means in the order of 100 volts to 10 kV, and low currents means in the order of tens of microamperes to milliamperes. Compared to circuits employing electro-magnetic devices for generating such high potentials, functionally equivalent circuits employing piezo-electric transformers are capable of being lighter-weight and more compact.

A conventional piezo-electric transformer circuit can incorporate a piezo-electric transformer comprising an elongate bar of PZT material comprising primary and secondary regions. In operation, an electrical drive signal is applied by the circuit to the primary region to excite vibrations therein which are coupled to the secondary region; the vibrations generate mechanical stresses in the secondary region and thereby high voltages therein, for example in the order of 1 kV. The high voltages are rectified to provide a high-voltage unipolar output from the circuit. The conventional transformer circuit suffers a problem that its efficiency deteriorates as its output is loaded; efficiency here is defined as a ratio of power delivered to a load connected to the output relative to input power provided to the circuit.

A United States patent no. 5 777 425 discloses a piezo-electric transformer comprising a rectangular plate of piezo-electric material. The transformer includes drive and pickup electrodes connected to a pulse generator for exciting the transformer at its mechanical resonance and thereby generating a high-voltage output. Applications for the transformer are disclosed in the patent,

namely in electronic copy machines, electrostatic air cleaners and for backlighting liquid crystal displays. The transformer is described as being fabricated from a known ceramic having a composition:

(a) Pb (Fe Nb) Zr Ti O_3; or

(b) Pb (Mn Sb) Zr Ti O_3; or

(c) Pb (Mn Nb) Zr TiO_3; or

(d) Pb (Fe Sb) Zr TiO_3.

Pb, Fe, Nb, Zr, Ti and O are chemical symbols corresponding to lead, iron, niobium, zirconium, titanium and oxygen respectively. Apart from disclosing the compositions, the patent does not indicate other properties required of the ceramics, for example their required mechanical Q-factor and charge coefficient.

In a published European patent application no. EP 0 730 338 A1, there is described a piezo-electric transformer for use in a low-power high-voltage power supply. The transformer is connected to an excitation circuit for driving the transformer at its resonance, and also connected to a diode rectification circuit for generating a unipolar high-voltage output potential. The transformer is described as optionally having a multilayer construction, layers of the transformer being mutually bonded by gluing, welding, brazing or similar. Piezo-electric materials suitable for fabricating the transformer are not disclosed in the published application.

In another published European patent application no. EP 0 665 600 A1, there is described a piezo-electric transformer and an associated electronic excitation circuit suitable for driving a high voltage discharge tube for backlighting liquid crystal displays. The application refers to a proprietary ceramic type HCEPC-28 made by Hitachi Metals Ltd. as being appropriate for fabricating the transformer. Moreover, the application refers to the transformer being of multilayer construction.

In the prior art, piezo-electric materials offering a relatively high piezo-electric coefficient are selected for high-power piezo-electric transformers; such relatively high piezo-electric coefficients are associated with relatively softer piezo-electric ceramics. Moreover, it is conventional practice

to design piezo-electric transformers to have associated operating resonant frequencies in the order of several tens of kHz.

The inventors have appreciated that it is not appropriate when designing high-power high-voltage power supplies incorporating piezo-electric transformers merely to select a piezo-electric transformer ceramic material purely on the basis of achieving a highest value of charge coefficient and mechanical resonance Q-factor to obtain maximum power supply conversion efficiency. Indeed, the inventors have appreciated to optimise the energy efficiency that piezo-electric ceramic dielectric loss is an important parameter which should be reduced to a relatively low level of substantially 0.005 or less at 1 kHz even at the expense of reducing charge coefficient.

According to a first aspect of the present invention, there is provided a piezo-electric transformer circuit incorporating a piezo-electric transformer comprising mutually vibrationally coupled primary and secondary regions, the secondary region operable to provide an output signal for use in generating an output from the circuit, and vibration exciting means for exciting the transformer into vibration at its resonant frequency to generate the output signal, characterised in that the transformer comprises a hard piezo-electric material having a dielectric loss of substantially 0.005 or less at 1 kHz frequency.

The invention provides the advantage that the piezo-electric transformer is capable of being operated more efficiently, especially when the output from the circuit is more heavily loaded.

A test frequency of 1 kHz is accepted in the art as being a standard reference frequency for measuring piezo-electric material dielectric loss and is widely quoted in prior art literature. Moreover, the dielectric loss of a piezo-electric material is defined as the tangent of an electrical loss angle observed when electrically driving the material.

A hard piezo-electric ceramic material is defined as a piezo-electric ceramic material exhibiting a hardness corresponding to a Navy type I or III ceramic. Such a hard material is to be contrasted with a soft piezo-electric material which exhibits a hardness corresponding to a Navy type II

ceramic. Further definitions mutually distinguishing Navy type I to III piezo-ceramic materials are to be found in a document United States standard MIL-STD-1376 which is herein incorporated by reference.

Conveniently, the exciting means is operable to excite vibrations at a frequency corresponding to a modal resonance of the primary and secondary regions. Operation at the modal resonance provides the advantage that vibration amplitude and associated stress levels in the transformer are magnified by a Q-factor of the resonance, thereby improving efficiency of the transformer compared to operation off-resonance.

Advantageously, the network is operable to phase shift and amplify the output signal to generate a drive signal for exciting and thereby sustaining vibrations within the transformer. Phase shifting and amplification provide a simple form of signal processing required for sustaining vibrations within the transformer. Preferably, the output signal is phase shifted in a range of 30° to 150° in the network to generate the drive signal.

It is desirable that the transformer should be capable of being driven to provide a high voltage magnification from the primary region to the secondary region. Thus, the exciting means advantageously incorporates amplifiers arranged in a bridge configuration operable to drive the transformer. The configuration enables the drive signal to have a peak-peak amplitude corresponding to up to twice a supply potential supplied to the amplifiers.

Advantageously, the exciting means incorporates at least one inductor through which the transformer is driven at its primary region, the inductor operable to electrically resonate with a capacitor provided by the primary region at a frequency corresponding to that of the vibrations. Incorporation of the inductor provides the advantages that:

(a) the primary region is capable of being tuned to appear as a resistive load to the drive signal; and

(b) higher harmonic components present in the drive signal can be attenuated, thereby counteracting spurious excitation of higher-order vibrational modes in the transformer and hence enhancing operating efficiency.

Conveniently, one of the inductors can incorporate a ferrite core. This enables the inductor to be compact.

Conveniently, the circuit incorporates rectifying means for rectifying the output signal from the secondary region to provide the output from the circuit, the output being in the form of a unipolar potential. Rectification provides the advantage of converting the output signal from the secondary region, namely an alternating signal, into a unipolar potential for output. Preferably, the rectifying means incorporates a rectifier diode operable to provide a conductive path for the output signal to a ground potential to assist with developing the unipolar output potential.

Advantageously, the transformer is operable to generate relatively high output potentials approaching 10 kV or more. To generate this potential, the transformer is operable to impart a greater voltage amplitude to the output signal relative to that of the drive signal.

Preferably, the transformer is operable to vibrate in a longitudinal mode of acoustic resonance. Longitudinal modes of vibration can be symmetrical modes of resonance, thereby assisting to reduce vibrational energy loss from the transformer in comparison to unsymmetrical vibrational modes. Conveniently, the transformer is of elongate form operable to vibrate longitudinally along its elongate axis.

Conveniently, the primary region comprises a stack of mutually joined piezo-electric material elements, each element incorporating electrical connections and arranged to be excited by the drive signal in parallel with other of the elements. Use of a plurality of elements assists the transformer to provide higher output potentials. Advantageously, the transformer incorporates in a range of 2 to 40 elements in the primary region and a single element in the secondary region.

In a second aspect of the invention, there is provided a method of operating a piezo-electric transformer, the method comprising the steps of:

(a) providing the transformer incorporating mutually vibrationally coupled primary and secondary regions, the secondary region providing an output signal from the transformer, the transformer being fabricated from a hard piezo-electric material having a dielectric loss of substantially 0.005 or less at 1 kHz; and

(b) establishing a feedback network for processing the output signal to generate a drive signal and applying the drive signal to excite oscillatory vibrations in the primary region which couple to the secondary region, thereby generating the output signal in the secondary region and sustaining the vibrations in the transformer.

In a third aspect of the present invention, there is provided a piezo-electric transformer comprising mutually vibrationally coupled primary and secondary regions, the primary region incorporating a stack of piezo-electric material elements, each element incorporating electrical connections for connecting a drive signal thereto and the secondary region incorporating electrical connections for extracting an output signal therefrom, characterised in that the piezo-electric transformer comprises a hard piezo-electric ceramic material having a dielectric loss of substantially 0.005 or less at 1 kHz. Use of the hard piezo-electric material, for example a Navy type I or III piezo-ceramic material, improves efficiency of the transformer compared to an identical transformer fabricated using a softer piezo-electrical material, for example a Navy type II piezo-ceramic material.

Conveniently, the primary region comprises a stack of mutually joined piezo-electric material elements, each element incorporating electrical connections and arranged to be excited by the drive signal in parallel with other of the elements. Use of a plurality of elements assists the transformer to provide higher output potentials. Advantageously, the transformer incorporates in a range of 2 to 40 elements in the primary region and a single element in the secondary region.

Embodiments of the invention will now be described, by way of example only, with reference to the following diagrams in which:

Figure 1 is an illustration of a piezo-electric transformer according to the invention;

Figure 2 is a schematic of an electrical equivalent circuit to the transformer shown in Figure 1;

Figure 3 is a schematic diagram of a circuit according to the invention for operating the transformer in Figure 1; and

Figure 4 is a schematic diagram of an alternative circuit according to the invention for operating the transformer in Figure 1.

Referring now to Figure 1, there is shown a piezo-electric transformer according to the invention; the transformer is indicated by 10 and comprises a primary region indicated by 12 and a secondary region indicated by 14. The regions 12, 14 are both identical in size, namely 8 mm long (l), 6 mm wide (w) and 2 mm thick (t). Exposed faces of the regions 12, 14 are mutually parallel or orthogonal. Moreover, the regions 12, 14 are each mutually joined at an interface 16 where each region provides an abutting face of size 6 mm x 2 mm.

The secondary region 14 incorporates an end face 18 on an opposite side thereof to the interface 16. The face 18 is metallized with a vacuum-deposited or sprayed metallic film, for example a silver metallic film, to which an electrical connection S1 is made by wire bonding.

The primary region 12 comprises a stack of sixteen piezo-electric planar elements, for example an element 20, each slice having a thickness of 100 μm and an area of 8 mm x 6 mm. When assembled, the stack is 2 mm thick to match the thickness (t) of the secondary region 14. Moreover, each element is metallized on its major faces with a vacuum-deposited metallic film, for example a silver metallic film. The major faces of each element are electrically mutually isolated. The elements are electrically connected in parallel in the stack to which primary electrical connections P1, P2 are made by wire bonding to exposed major faces of an upper element 20a and a lower element 20b respectively of the primary region 12. The connections P1, P2 can alternatively be made to opposite side edges of the primary region 12 where metallic film connections on the major faces of the elements are accessible.

The elements 20 and the secondary region 14 comprise a hard PZT piezo-electric ceramic material exhibiting a dielectric loss of 0.005 or less at a test frequency of 1 kHz. The hard material has a product reference PZT26 and is manufactured by a Danish company Ferroperm A/S, Hejreskovvej 18A, DK-3490 Kvistgaard, Denmark. The hard PZT26 material is to be contrasted with softer piezo-electric materials having product references PZT27 and PZT29 from the same company. The softer PZT27 and PZT29 materials exhibit reduced resonance Q-factors and greater dissipation when vibrating compared to the hard PZT26 material; moreover, such softer PZT materials exhibit a higher dielectric loss in the order of 0.02 at 1 kHz. Here, the dielectric loss of a piezo-electric material is defined as the tangent of the electrical loss angle observed when electrically driving the material. The dielectric loss also represents the ratio of resistance to reactance of a parallel equivalent circuit of a piezo-electric transformer made from the material. The dielectric loss can be measured directly using an impedance bridge, for example at an excitation frequency of 1 kHz.

Table 1 contrasts material parameters associated with the hard PZT26 piezo-ceramic material with corresponding material parameters associated with the softer PZT27 and PZT 29 piezo-ceramic materials.

Table 1

Parameter	PZT26 (hard)	PZT27 (soft)	PZT29 (soft)
Relative dielectric constant @ 1 kHz	1300	1800	2900
Dielectric loss factor (tan δ)	0.003	0.017	0.019
Curie temperature (^{o}C)	330	350	235
Coupling factor k_{33}	0.68	0.7	0.75
Piezo-electric charge coefficient (10^{-12} C/N), $-d_{31}$	130	170	240
Density (10^{3} kg/m^{3})	7.70	7.70	7.45
Resonant mechanical Q_m factor	>1000	80	90

During manufacture, the elements and the secondary region 14 are poled prior to being joined together using a rigid epoxy bonding agent to fabricate the transformer 10. Poling involves

applying a momentary electric field to the region 14 and the elements of sufficient magnitude to cause a permanent electrical polarisation therein; the polarisation is reversible by heating to or above the Curie temperature in Table 1 or by applying a sufficiently powerful depolarising electric field.

When assembled for operation, the transformer 10 can be mounted onto compliant air-filled expanded plastic foam. It can alternatively be supported on point mounts which engage onto areas of the transformer 10 corresponding to vibrational nodes when the transformer 10 is vibrating; such point mounts assist to enhance resonance Q-factor of the transformer 10 when resonating at one or more of its resonant modes by reducing vibrational energy loss therefrom. The use of foam plastics provides a robust shock-resilient mount for the transformer 10, thereby assisting to counteract fracture of the transformer 10 when subjected to high g-forces, for example accelerations in excess of 10g.

Operation of the transformer 10 will now be described with reference to Figure 1. The connections P1, P2 are connected to a source (not shown in Figure 1) providing a drive signal which imposes an alternating drive potential difference between the connections P1, P2. Because the elements are polarised in a first direction parallel to an arrow 22, namely in a direction normal to major surfaces of the elements, the elements expand and contract in the first direction in response to the drive signal. This expansion and contraction of the elements in the first direction results in them exhibiting an associated lateral expansion and contraction in second and third directions indicated by arrows 24, 26 respectively. The arrows 22, 24, 26 are mutually perpendicular. On account of the primary and secondary regions 12, 14 being joined together and thereby vibrationally coupled together, the secondary region 14 vibrates in sympathy with the primary region 12. Since the secondary region 14 is polarised in a direction parallel to the arrow 26, acoustic vibrations in the secondary region 14 are capable of developing an alternating potential at the connection S1.

The transformer 10 is capable of vibrating in a number of different resonance modes depending upon the frequency of the drive signal applied, each mode corresponding to a different manner in which the transformer 10 is capable of flexing. When the frequency of the drive signal corresponds to that of a particular mode, that particular mode becomes preferentially excited. The degree to

which the mode is excited depends upon the magnitude of the drive signal and also on effectiveness of excitation of the mode from the connections P1, P2.

The transformer 10 is designed to function in a longitudinal mode of resonance at 100 kHz in which the regions 12, 14 alternately expand and contract in opposition in directions parallel to the arrow 26. This mode of operation results in there arising most motion at extremities of the regions 12, 14 remoter from the interface 16 and least motion at the interface 16; in other words, the interface 16 functions as a nodal point and exposed ends of the regions 12, 14 functional as antinodal points. When the secondary region 14 vibrates, stresses arising from periodic elongation thereof result in generation of an alternating potential at the connection S1. The transformer 10 is thereby capable of converting a relatively smaller drive potential applied to the primary region 12 between the connections P1, P2 into a corresponding relatively larger magnified potential at the connection S1. For example, a 5 volt peak-peak 100 kHz sinusoidal signal applied to the connections P1, P2 can result in generation of a 300 volt peak-peak sinusoidal signal at the connection S1. Signal magnification provided by the transformer 10 is referred as its magnification factor, N. The factor N is determined by physical dimensions of the transformer 10, namely its dimensions t and l, as well as its Q-factor associated with its longitudinal mode of resonance and also piezo-electric coupling coefficients associated with the primary and secondary regions 12, 14 respectively. Equation 1 expresses this relationship:

$$N = \frac{Q_m k_0 k_{13} k_{33} l}{t} \qquad \text{Eq. 1}$$

where

Q_m = resonant mechanical Q factor;

k_0 = proportionality coefficient;

k_{13} = primary region coupling coefficient associated with coupling of piezoelectrically induced stress arising from applying an electric field in a primary region poling direction to stress in a direction perpendicular to the poling direction;

k_{33} = secondary region coupling coefficient associated with coupling stress in the secondary region poling direction to a corresponding secondary electric field in the poling direction;

l = length of primary and secondary regions; and

t = thickness of primary and secondary regions.

Incorporation of a plurality of planar elements into the primary region 12 increases current output performance of the transformer 10 compared to a piezo-electric transformer of similar external physical dimensions and material incorporating only a single element in its primary region.

Referring now to Figure 2, there is shown an electrical equivalent circuit to the transformer 10, the circuit being indicated by 100. Components in the circuit 100 do not exist in reality but represent mechanical resonance characteristics of the primary and secondary regions 12, 14 near their 100 kHz longitudinal resonance mode.

The primary region 12 includes the connections P1, P2 which are mutually connected through a series resonant circuit comprising an inductor Lp, a capacitor Cp and a resistor Rp; the series resonant circuit is resonant at a frequency fp. Moreover, the connections P1, P2 are also mutually connected through two capacitors Cep connected in series. The capacitors Cep represent an electrical capacitance between metallisation layers incorporated onto the slices in the primary region 12 and are each in the order of several hundred nanofarads. The series resonant circuit represents mechanical resonance of the primary region 12 when vibrating in its longitudinal mode of vibration.

The secondary region 14 includes a parallel resonant circuit comprising a resistor Rs, an inductor Ls and a capacitor Cs connected in parallel with a current source Is. The parallel resonant circuit is resonant at a frequency fs. The current source Is incorporates two terminals, namely:

(a) a first terminal connected to one side of the parallel resonant circuit and also to a junction where the capacitors Cep mutually join; and

(b) a second terminal connected to another side of the parallel resonant circuit and also to the connection S1.

In operation, most power is delivered to the primary region 12 when a drive signal applied across the connections P1, P2 is a sinusoidal signal having a frequency equal to fp. When the series resonant circuit is driven at resonance, it presents a resistive load Rp across the connections P1, P2. However, the capacitors Cep appear in parallel with Rp and provide a capacitive load to the connections P1, P2; as a consequence, a primary current ip supplied to the connections P1, P2 is phase advanced relative to a potential developed across the connections P1, P2 at the frequency fp. The inventors have appreciated that determination of current-voltage phase difference when driving the primary region 12 is not an optimal manner in which to ensure that the transformer 10 is operating efficiently at resonance because it is difficult to determine precisely when the series resonant circuit is being driven at its resonant frequency fp.

In operation, the parallel resonant circuit in the secondary region 14 exhibits a slightly different resonant frequency relative to the series resonant circuit in the primary region 12; this corresponds to fp and fs being unequal, namely there arises a frequency difference Δf equal to fs-fp. This frequency difference varies depending upon load applied to the terminal S1. Thus, the inventors have appreciated that operating the primary region 12 at its resonant frequency fp does not necessarily ensure that the secondary region 14 is being operated precisely at its resonance. In consequence, it is found that efficiency of operation of the transformer 10 reduces considerably when a load is applied to the connection S1.

When resonating in its longitudinal mode at 100 kHz and unloaded, the transformer 10 exhibits a resonance Q-factor of approximately 300. When loaded at the connection S1, this Q-factor can reduce to 60 which modifies Δf. Mechanisms for acoustic energy loss from the transformer 10 which determine its Q-factor include:

(a) intrinsic losses within the PZT material arising from frictional losses at PZT particle grain boundaries therein;

(b) air damping effects;

(c) acoustic losses to a foam or point mount employed to support the transformer 10; and

(d) electrical load applied to the connection S1 which absorbs acoustic energy from the secondary region 14.

In operation, mechanism (d) is most significant at changing the Q-factor and hence Δf.

The inventors have appreciated that driving the transformer 10 closer to its optimum operating condition is a complex problem. Whereas fixed frequency primary drive is conventionally employed in piezo-electric transformer power supplies, the inventors have realised that output from the secondary connection S1 provides a most reliable signal from which to derive a drive signal for the primary region 12 which enables the transformer 10 to operate more efficiently when loaded at its secondary region 14.

Referring now to Figure 3, there is shown a schematic diagram of a circuit according to the invention for operating the transformer 10. The circuit is indicated by 200 and comprises:

(a) the piezo-electric transformer 10;
(b) a bias network indicated by 210 and included within a dotted line 220;
(c) first and second amplifiers indicated by 230, 250 and included within dotted lines 240, 260 respectively;
(d) a feedback network indicated by 270 and included within a dotted line 280; and
(e) an output network indicated by 290 and included within a dotted line 300.

The circuit 200 is connected to supply lines Vs and 0v which are operable to provide input power to the circuit 200.

The bias network 210 incorporates two 100k resistors R1, R2 connected in series, namely the resistors R1, R2 are each connected at one end thereof to the supply lines Vs, 0v respectively. The resistors R1, R2 are operable to provide a bias potential where they are mutually connected.

The amplifiers 230, 250 are identical and each incorporates an operational amplifier connected to the supply lines Vs, 0v. The operational amplifiers are arranged in inverting configuration with resistors R3, R4 defining a voltage gain provided by the first amplifier 230 and resistors R5, R6 defining a voltage gain provided by the second amplifier 250. The resistors R3, R6 are 470k

resistors and the resistors R4, R5 are 3M3 resistors. The bias network 210 is connected to the amplifiers 230, 250 and operable to provide a bias potential thereto. Outputs from the amplifiers 230, 250 are connected to connections P1, P2 of the transformer 10 respectively. The amplifier 230 incorporates an input which is connected to an output from the feedback network 270, and the amplifier 250 incorporates an input which is connected to the output from the amplifier 230.

The feedback network 270 comprises a 2M2 resistor R7 and a 10 pF capacitor C1 connected in series to the supply line 0v. The resistor R7 provides a input which is connected to the connection S1 of the transformer 10. A junction where the resistor R7 is joined to the capacitor C1 provides a output which is connected to the input of the amplifier 230 through a 100 nF coupling capacitor C3.

The output network 290 comprises two silicon rectifier diodes D1, D2 exhibiting a reverse breakdown voltage of approximately 1kV and a fast switching speed of 100 ns or less. The diode D1 is connected by its cathode to the connection S1 and its anode to the supply line 0v. Moreover, the diode D2 is connected by its anode to the connection S1 and its cathode to a secondary output S2 from the circuit 200. Furthermore, the network 290 also incorporates a 100nF output capacitor C2 connected between the output S2 and the 0v supply line. In operation, a high voltage potential of several hundred volts relative to the supply line 0v is provided at the output S2. The diode D1 is arranged to provide a discharge path to the supply line 0v to assist with developing the high potential at the output S2.

The feedback network 270 is arranged to exhibit a time constant which is at least five times longer than a cycle time period associated with the frequency fs. This ensures that a signal provided by the network 270 to the amplifier 230 is approximately in a range of 30° to 90° phase shifted relative to an output signal provided by the transformer 10 at the connection S2; the phase shift is necessary for the circuit 200 to maintain oscillation. However, the circuit 200 is capable of oscillating satisfactorily for a phase shift in a range of 30° to 150° in the network 270; extra components are required in the network 270 to obtain phase shifts in excess of 90°.

Operation of the circuit 200 will now be described with reference to Figure 3. When power is supplied through the supply lines Vs, 0v to the circuit 200, the bias network 210 provides a bias potential to the amplifiers 230, 250, the bias potential substantially intermediate between Vs and 0v. The bias potential biases the amplifiers 230, 250 to operate symmetrically with reference to the bias potential.

The amplifiers 230, 250 provide voltage gain around a feedback loop comprising the transformer 10, the feedback network 270 and the amplifiers 230, 250. The feedback loop is arranged to have greater than unity gain therearound at the frequency fs, namely at approximately 100 kHz; the feedback network 270 provides a phase shift required for sustaining oscillation around the loop. When the circuit 200 is initially energised, noise injected into the circuit 200 by the amplifiers 230, 250 becomes amplified around the feedback loop to establish a major oscillation at the frequency fs. This feedback loop provides the advantage that the circuit 200 will automatically restart in the event of its supply lines being momentarily interrupted or the transformer 10 being subjected to violent shock which disturbs its vibration.

As illustrated in Figure 2, the secondary connection S1 is capacitively coupled within the transformer 10 to the primary connections P1, P2. As a consequence, the diode D1 provides a discharge path for the connection S1 during a first half cycle and the diode D2 provides a charging path to charge the capacitor C2 during a second half cycle. The capacitor C2 thereby becomes progressively charged in operation to a high potential of several hundred volts. The high potential is a unipolar potential.

The circuit 200 incorporates an important feature that the primary connections P1, P2 are driven by a signal derived from the secondary connection S1. This feature enables the circuit 200 to adapt to changes in the secondary region 14 resonant frequency fs in response to loading applied to the output S2, thereby enhancing efficiency of the circuit 200 under load conditions.

The amplifiers 230, 250 are connected in bridge configuration. This configuration provides the advantage that the amplifiers 230, 250 are capable of driving the transformer 10 with a drive signal across its primary connections P1, P2 which has a peak-peak voltage amplitude of approximately

twice that of a potential different between the supply lines Vs, 0v. Thus, this configuration makes the circuit 200 capable of providing a high output voltage approaching several hundred volts when operating on a supply line potential difference of 5 volts.

It is important that the diodes D1, D2 are capable of switching sufficiently rapidly to counteract the diodes D1, D2 momentarily both conducting and thereby shorting the capacitor C2 to the supply line 0v; if the diodes D1, D2 switch insufficiently rapidly, operating efficiency of the circuit 200 is degraded. Small junction area silicon diodes incorporating graded doped junctions to give high inverse breakdown voltage characteristics are especially suitable for use as the diodes D1, D2.

Although the circuit 200 is arranged to excite the transformer 10 therein to vibrate in its longitudinal mode at resonance at a frequency of 100 kHz, the circuit 200 can be adapted to operate at a higher resonance mode of the transformer 10, or example at 200 kHz; to achieve operation at such a higher-order mode, the feedback network 270 can incorporate a bandpass filter adapted to preferentially transmit signals in a frequency range of the higher-order mode, thereby enabling the feedback loop to maintain oscillation in the frequency range of the higher order mode and not at lower order modes. Such higher frequency operation provides the advantage that less ripple is evident at the output S2 although the diodes D1, D2 need to be capable of switching more rapidly in order to counteract increased switching losses occurring as a consequence of operating at higher frequencies.

Referring now to Figure 4, there is shown a schematic diagram of an alternative circuit according to the invention for operating the transformer 10. The alternative circuit is indicated by 400 and is identical to the circuit 200 except that an inductor L1 is incorporated between the output of the amplifier 250 and the connection P2 of the transformer 10. The inductor L1 is arranged to exhibit an inductance which is resonant at the frequency fs with the series connected capacitors Cep shown in Figure 2.

Incorporation of the inductor L1 provides the advantages that:

(a) the primary region can be tuned so that longitudinal resonance thereof corresponds to the current ip and a drive potential applied across the connections P1, P2 being mutually in phase; and

(b) inclusion of the inductor L1 assists to prevent square-wave drive signals provided by the amplifiers 230, 250 from spuriously exciting higher-order resonance modes in the transformer 10 when attempting to drive it at its fundamental longitudinal vibrational mode. Spurious oscillation can arise when the drive signal is a square wave signal including an extensive spectrum of odd harmonics whose associated frequencies can coincide with frequencies of higher order resonant modes of the transformer 10.

The inductor L1 can be fabricated by winding enameled copper wire around a small ferrite bead to provide an inductance in the order of 30 μH to resonate at 100kHz with the capacitors Cep. Use of a ferrite bead provides a compact miniature inductor assembly. Alternatively, the inductor L1 can be fabricated as an air-cored coil; such construction is more attractive for higher power applications. Moreover, if required, the inductor L1 can comprise a plurality of smaller inductors connected together.

Experimental verification has demonstrated that inclusion of the inductor L1 improves operating efficiency of the circuit 400 compared to the circuit 200.

In a modified version of the circuit 400, an additional inductor is incorporated between the connection S1 and the networks 270, 290; inclusion of this inductor further enables fine tuning of the transformer 10 to be achieved. The additional inductor is arranged to resonate with a capacitance provided by the transformer 10 at its connection S1 at a frequency corresponding to that of a operational mechanical resonance of the transformer 10. Moreover, in a further modified version of the circuit 400, there can be incorporated the additional inductor connected to the connection S1 as described above with the inductor L1 omitted.

It will be appreciated by those skilled in the art that modifications to the transformer 10 and to the circuits 200, 400 can be made without departing from the scope of the invention. For example, the transformer 10 can incorporate in a range of 2 to 40 elements. Moreover, physical dimensions of

the transformer 10 can be modified, for example it can be made smaller to operate at a relatively higher frequency, or it can be made longer and thinner to provide it with an enhanced magnification factor N. The enhanced magnification factor is desirable when greater output potentials are to be generated.

With regard to construction of the transformer 10, its elements can be assembled by eutectic metal bonding techniques instead of employing rigid epoxy agents; such techniques provide a higher Q-factor to a transformer thereby fabricated. Moreover, the transformer 10 can be adapted to incorporate one primary region and two secondary regions bonded onto opposing side faces of the primary region, this provides the advantage that greater secondary region output currents can be thereby obtained.

Although hard PZT materials are used for fabricating the transformer 10, alternative hard man-made piezoelectric materials can be substituted if necessary, for example materials incorporating piezo-electric polyvinylidene fluoride (PVDF).

The transformer 10 and its associated circuits 200, 400 are capable of providing high potentials suitable for operating high voltage sensors, for example miniature Geiger-Muller tubes for detecting ionising radiation, as well as assisting to provide rear illumination in back-lit liquid crystal displays. Since the transformer 10 and its circuits 200, 400 are capable of being compact, they can be incorporated into personnel-wearable equipment, for example portable electronic radiation dose monitors including solid state memory for data recordal purposes.

CLAIMS

1. A piezo-electric transformer circuit (200) incorporating a piezo-electric transformer (10) comprising mutually vibrationally coupled primary and secondary regions (12, 14), the secondary region (14) operable to provide an output signal for use in generating an output from the circuit (200), and vibration exciting means (210, 230, 250, 270) for exciting the transformer (10) into vibration to generate the output signal, characterised in that the transformer (10) comprises a hard piezo-electric material having a dielectric loss of substantially 0.005 or less at 1 kHz frequency.

2. A circuit according to Claim 1 wherein the exciting means (210, 230, 250, 270) is operable to excite vibrations at a frequency corresponding to a modal resonance of the primary and secondary regions.

3. A circuit according to Claim 1 or 2 wherein the exciting means incorporates a network (270) operable to phase shift and amplify the output signal to generate a drive signal for exciting and thereby sustaining vibrations within the transformer (10).

4. A circuit according to Claim 3 wherein the network (270) is operable to phase shift the output signal in a range of 30° to 150° to generate the drive signal.

5. A circuit according to Claim 3 wherein the network (270) is operable to phase shift the output signal in a range of 30° to 90° to generate the drive signal.

6. A circuit according to any one of Claims 1 to 5 wherein the exciting means incorporates amplifiers (230, 250) arranged in a bridge configuration operable to drive the transformer (10).

7. A circuit according to any one of Claims 1 to 6 wherein the exciting means (210, 230, 250, 270) incorporates at least one inductor through which the transformer (10) is driven at its

primary region (12), the inductor operable to electrically resonate with a capacitor provided by the primary region (12) at a frequency corresponding to that of the vibrations.

8. A circuit according to Claim 7 wherein said at least one inductor incorporates a ferrite core.

9. A circuit according to any preceding claim incorporating rectifying means (290) for rectifying the output signal from the secondary region to provide the output from the circuit, the output being in the form of a unipolar output potential.

10. A circuit according to Claim 9 wherein the rectifying means(290) incorporates a rectifier diode (D1) operable to provide a conductive path for the output signal to a ground potential to assist with developing the unipolar output potential.

11. A circuit according to any preceding claim wherein the transformer (10) is operable to impart a greater voltage amplitude to the output signal relative to that of the drive signal.

12. A circuit according to any preceding claim wherein the transformer (10) is operable to vibrate in a longitudinal mode of acoustic resonance.

13. A circuit according to any preceding claim wherein the primary region (12) of the transformer (10) comprises a stack of mutually joined piezo-electric material elements (20), each element (20) incorporating electrical connections and arranged to be excited in parallel with other of the elements (20).

14. A circuit according to Claim 13 wherein the transformer (10) incorporates in a range of 2 to 40 elements in the primary region (12) and a single element in the secondary region (14).

15. A method of operating a piezo-electric transformer (10), the method comprising the steps of:

(a) providing the transformer (10) incorporating mutually vibrationally coupled primary (12) and secondary (14) regions, the secondary region (14) providing an output signal from the transformer (10), the transformer (10) being fabricated from a hard piezo-electric material having a dielectric loss of substantially 0.005 or less at 1 kHz; and

(b) establishing a feedback network (210, 230, 250, 270) for processing the output signal to generate a drive signal and applying the drive signal to excite oscillatory vibrations in the primary region (12) which couple to the secondary region (14), thereby generating the output signal in the secondary region and sustaining the vibrations in the transformer.

16. A method according to Claim 15 wherein the vibrations are at a frequency corresponding to a modal resonance of the primary and secondary regions (12, 14).

17. A method according to Claim 15 or 16 wherein the output signal is phase shifted and amplified in the network (210, 230, 250, 270) to generate the drive signal.

18. A method according to Claim 17 wherein the output signal is phase shifted in a range of 30° to 150° in the network (270) to generate the drive signal.

19. A method according to Claim 15, 16, 17 or 18 wherein the transformer (10) is driven from amplifiers (230, 250) arranged in a bridge configuration.

20. A method according to any one of Claims 15 to 19 wherein the transformer (10) is driven at its primary region (12) through at least one inductor arranged to electrically resonate with a capacitor provided by the primary region (12) at a frequency corresponding to that of the vibrations.

21. A method according to Claim 20 wherein said at least one inductor incorporates a ferrite core.

22. A method according to Claim 20 or 21 wherein signals from the secondary region (14) of the transformer (10) are extracted through an inductor arranged to electrically resonate

with a capacitance provided by the secondary region (14) at a frequency corresponding to that of the vibrations.

23. A method according to any one of Claims 15 to 22 wherein the output signal is rectified to provide a unipolar output potential (S2) from the transformer (10).

24. A method according to Claim 23 wherein the output signal is directed through a rectifier diode (D1) to a ground potential, the diode (D1) operative to provide a conductive path to assist with developing the unipolar output potential.

25. A method according to any one of Claims 15 to 24 wherein the transformer (10) is of elongate form operable to vibrate longitudinally along its elongate axis.

26. A method according to any one of Claims 15 to 25 wherein the transformer (10) is operable to impart a greater voltage amplitude to the output signal relative to the drive signal.

27. A method according to one of Claims 15 to 26 wherein the transformer (10) is operable to vibrate in a longitudinal mode of mechanical resonance.

28. A method according to any one of Claims 15 to 27 wherein the primary region (12) comprises a stack of mutually joined piezo-electric material elements (20), each element (20) incorporating electrical connections and arranged to be excited by the drive signal in parallel with other of the elements.

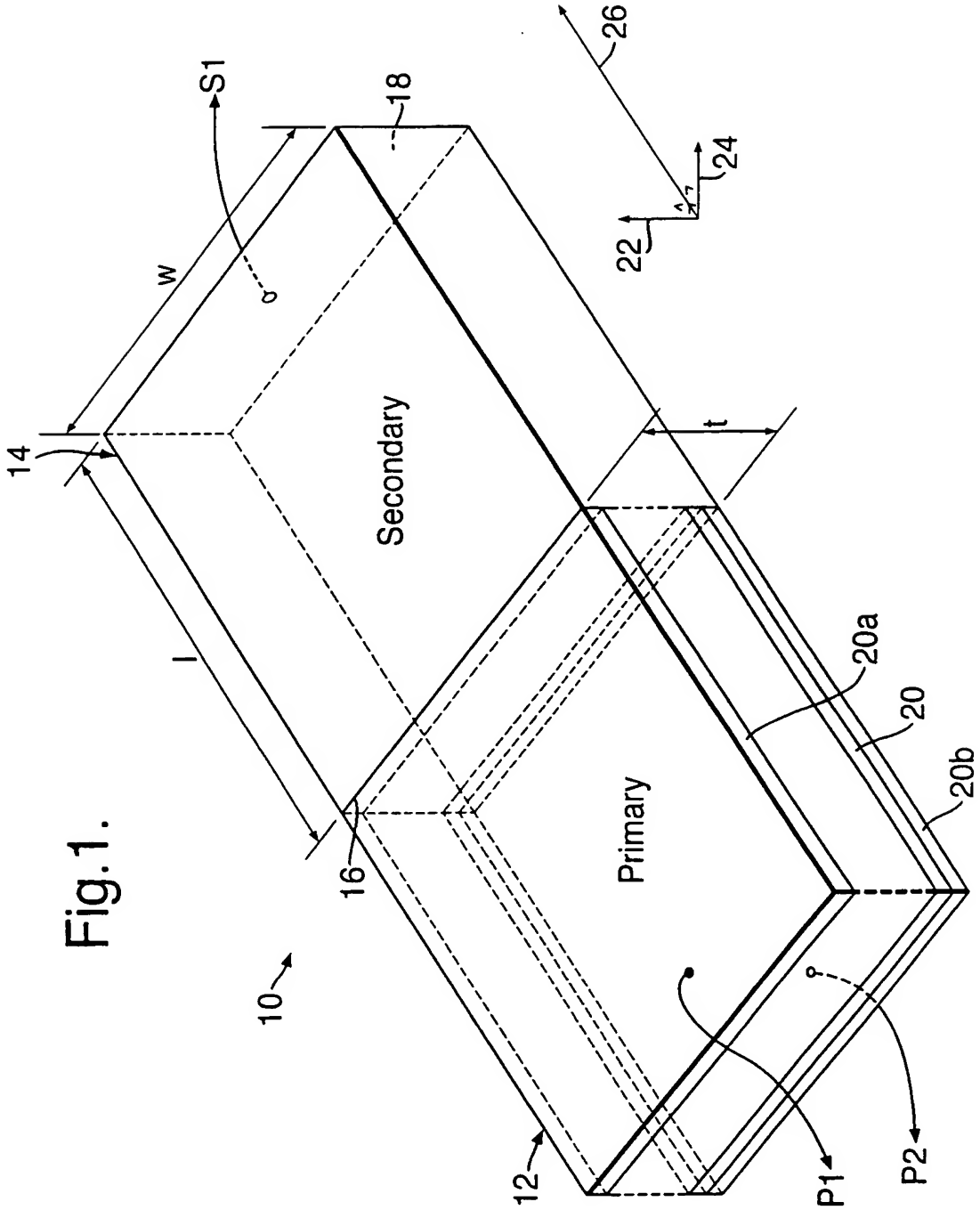
29. A method according to Claim 28 wherein the transformer (10) incorporates in a range of 2 to 40 elements in the primary region (12) and a single element in the secondary region (14).

30. A personnel-wearable sensing apparatus operable according to a method claimed in any one or more of Claims 15 to 19 for generating an elevated bias potential for use in the apparatus.

31. A piezo-electric transformer (10) comprising mutually vibrationally coupled primary (12) and secondary regions (14), the primary region (12) incorporating a stack of piezo-electric material elements (20), each element (20) incorporating electrical connections for connecting a drive signal thereto and the secondary region (14) incorporating electrical connections for extracting an output signal therefrom, characterised in that the transformer (10) comprises a piezo-electric material having a dielectric loss of substantially 0.005 or less at 1 kHz.

32. A transformer according to Claim 30 or 31 wherein the transformer (10) incorporates in a range of 2 to 40 elements in the primary region (12), and a single element in the secondary region (14).

33. A personnel-wearable sensing apparatus incorporating a transformer (10) according to any one of Claims 31 to 32, the transformer (10) operable to generate a bias potential for use in the apparatus.


26
S1
18
24
22
w
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20b
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Fig.1.

Fig.2.

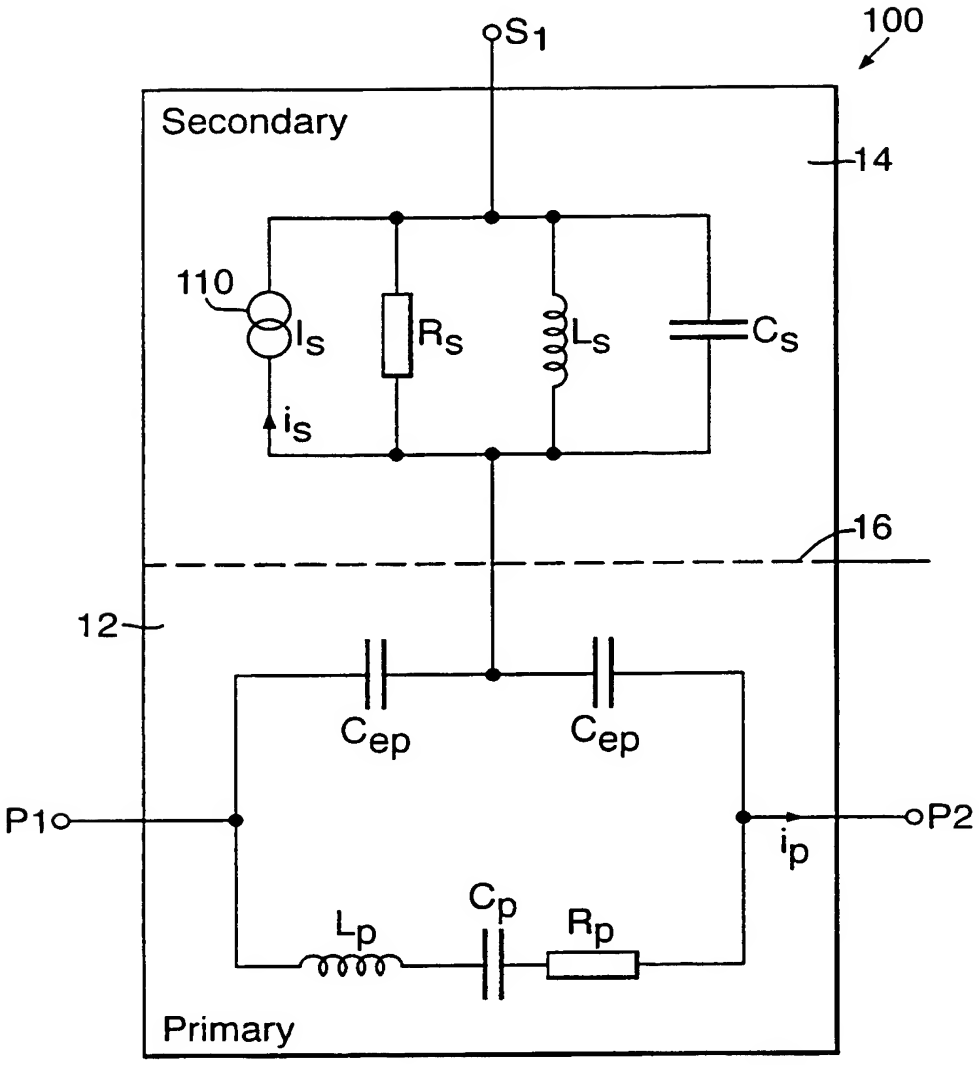
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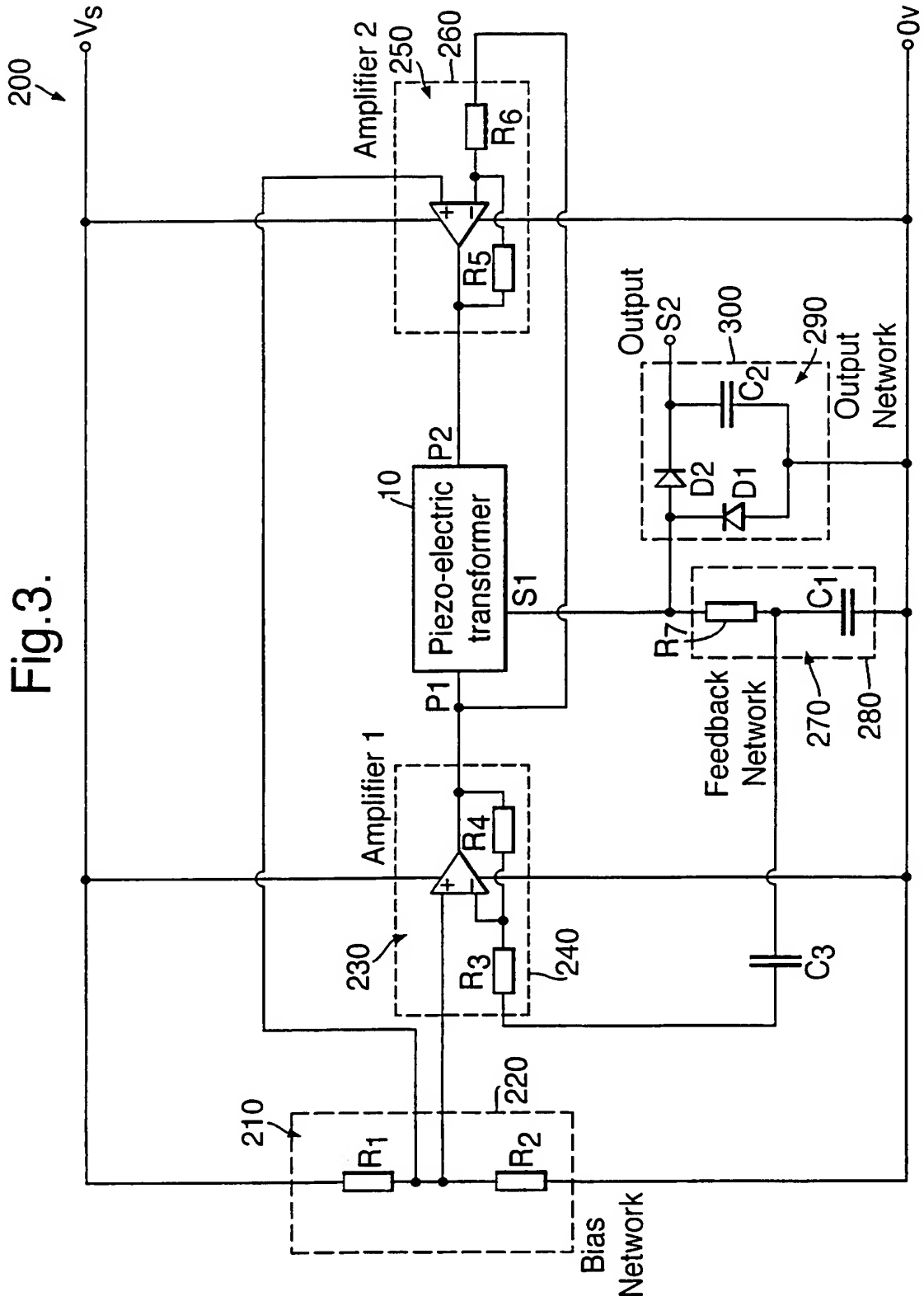
Fig.3.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Vs
0v
Amplifier 2
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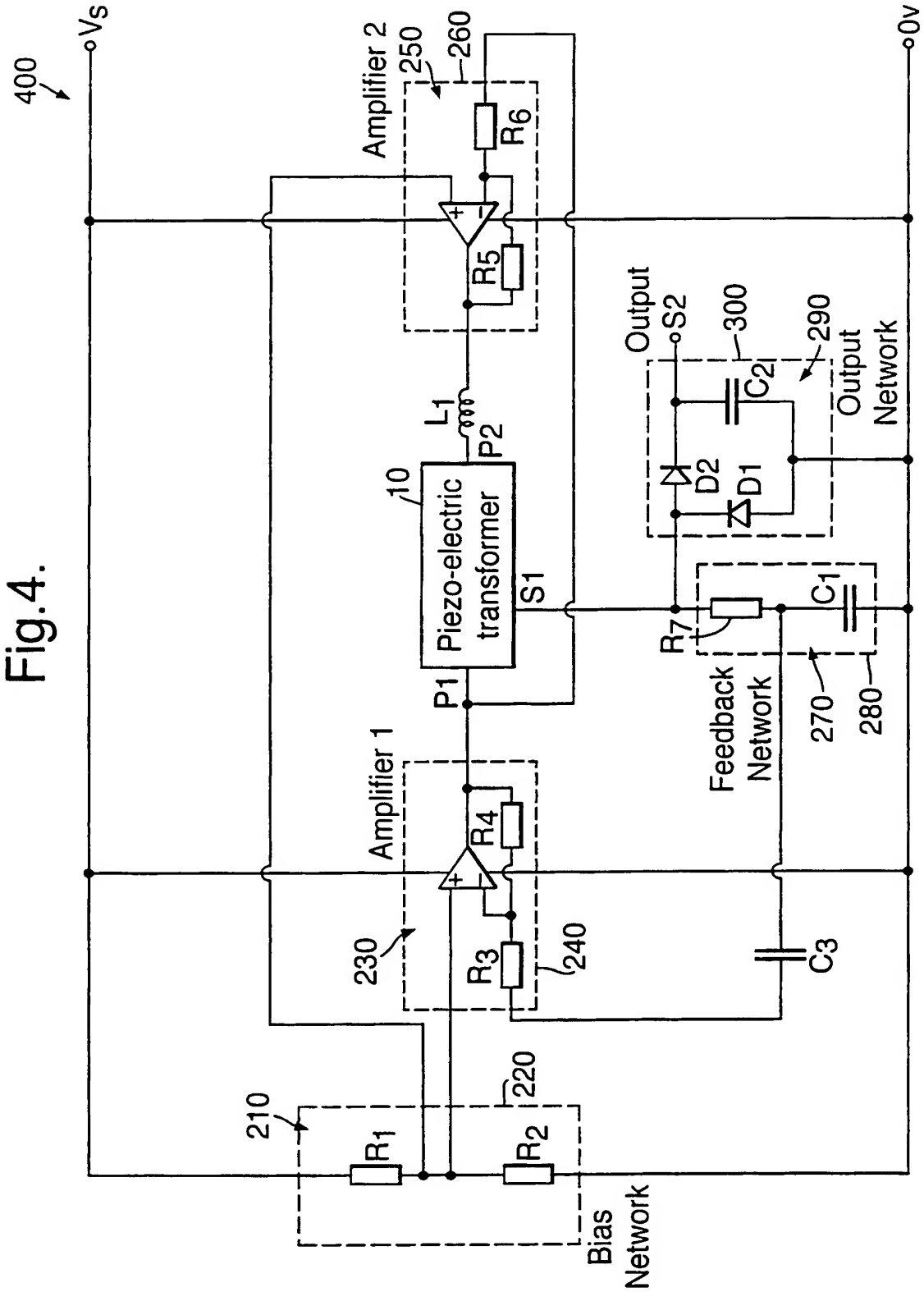
260
R6
R5
Output
S2
300
290
C2
Output Network
D2
D1
P2
10
Piezo-electric transformer
S1
P1
R7
C1
Feedback Network
270
280
Amplifier 1
R4
230
R3
240
C3
220
210
R1
R2
Bias Network

Fig.4.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Vs
0v
Amplifier 2
250
260
R6
R5
L1
P2
10
Piezo-electric transformer
S1
P1
Amplifier 1
R4
R3
230
240
210
220
R1
R2
Bias Network
Output
S2
300
290
C2
Output Network
D2
D1
R7
C1
Feedback Network
270
280
C3

INTERNATIONAL SEARCH REPORT

Inter[illegible]pplication No
PCT/GB 00/02418

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01L41/107

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
INSPEC, COMPENDEX, EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KUANG A X ET AL: "Piezoelectric ceramic transformer high voltage power supply" ISAF '86. PROCEEDINGS OF THE SIXTH IEEE INTERNATIONAL SYMPOSIUM ON APPLICATIONS OF FERROELECTRICS, BETHLEHEM, PA, USA, 8 - 11 June 1986, pages 689-692, XP002147549 IEEE, New York, USA	1-3,7, 11, 15-17, 20,22,26
Y	the whole document	4-6,13, 14,18, 19,28,29
Y	US 5 866 968 A (MECH HAROLD W) 2 February 1999 (1999-02-02) column 1, line 11 -column 5, line 54 column 7, line 37 - line 41 figures 1,2	4-6,18, 19

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 September 2000	29/09/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Köpf, C

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 736 446 A (BERLINCOURT DON A ET AL) 29 May 1973 (1973-05-29) column 1, line 8 -column 6, line 41 column 10, line 16 -column 11, line 56 figures 1,7,10	1-3, 9-12, 15-17, 23-27
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